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Original communication

Identifying sexual dimorphism in a paediatric South Indian population using stepwise discriminant function analysis☆

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ABSTRACT

Anthropological research relies on skeletal and dental remains for the identification of species. Sexual dimorphism is the systematic difference in form between males and females of the same species. This study is designed to compute a new formula for sex determination using discriminant function analysis in the deciduous crown dimensions of a paediatric population of South Indian origin and to check its accuracy. The sample consisted of 93 females and 90 males of South Indian origin aged between 5 and 13 years. Alginate impressions of the upper dental arch were made and casts were poured immediately. A digital vernier calliper was used to obtain measurements. Teeth considered for measurement were deciduous maxillary canines and molars. Our study is a maiden attempt in considering diagonal measurements along with mesiodistal (MD) and buccolingual (BL) dimensions as predictor variables for sex determination. Statistical analysis was performed using the Statistical Package for the Social Science version 17.0 software. By using the Student *t*-test, the different predictor variables of teeth selected between male and females were found to be significant ($p < 0.05$). Highly significant sexual dimorphism was found in the mean MD dimension of maxillary right canine and right and left first molar, BL dimension of right first molar, distobuccal–mesiolingual of right and left first molar and right second molar and mesiobuccal–distolingual of right second molar. The percentage of sexual dimorphism in MD dimensions revealed that the right upper first molar was the most dimorphic tooth and the upper first molar of the left side was the least dimorphic of the six teeth studied. The present study found the level of sexual dimorphism in the deciduous crown dimensions of a selected group of South Indian population, which is sufficiently large to determine sex with an accuracy of 87.2–88% by discriminant function analysis. Hence the formula derived from the present study could be of some value in sex determination of paediatric populations of South Indian origin.

1. Introduction

Forensic science often uses the skeletal dental remains as sources for human identification; in particular, the teeth are unique as they are always protected in a hard casting.[1] They are tissues characterised by structures with extraordinary resistance to putrefaction and effects of external agents that cause destruction of soft tissues of the body. Hence, teeth form an excellent structure for forensic investigation.[2]

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Sexual dimorphism is the systematic difference in form between males and females of the same species. Identification of sex is more significant in narrowing down a victim. It allows the exclusion of one-half of the population, thereby aiding a more precise search for the identity of the deceased.[3]

Sexual dimorphism in the dental tissue is of monumental value to the physical anthropologist due to its applications in forensic identification.[4] Odontometric data provide insignificant trait differences amongst and within a population, but form a stronger evidence for identification purposes.[5]

These differences not only reflect the ongoing process of evolution and provide a method for studying the evolutionary mechanism, but also represent the variation that must be considered in the daily care of patients.[6]

Traditionally, mesiodistal (MD) and buccolingual (BL) diameters of the crowns of teeth form the basis for assessing sex differences. Several studies have been conducted, which demonstrated significant sexual dimorphism in dimensions of permanent[7–12] and deciduous crowns using diagnostic dental casts.[13–19]

This study emphasises the importance of teeth in sexual dimorphism for the following reasons: (1) the pelvis, which is the most precise structural indicator, may be fragmented, (2) sex characteristics in paediatric bone are not fully developed[1] and (3) DNA analysis can give precise results, but is expensive and relatively time consuming.[20]

If sexual dimorphism in deciduous dentition is proved for its significance in sex determination like permanent dentition,[7–12] then it could be useful to precisely identify the sex of the children. Deciduous dentition-based studies have been carried out by Black TK,[21] DeVito and Saunders[22] and Zadzinska et al.[23]; they have published a series of discriminant functions for sex determination. On a thorough search of the literature in the English language, there is however no such evidence explored in the Indian population for deciduous dentition.

The magnitude and pattern of sexual dimorphism in the size of teeth differ from one population to another. Hence there is a need for finding out differences in the odontometric parameters in deciduous dentition amongst males and females of Indian natives with discriminant function, which may aid in establishing sex in juveniles.

Both MD and BL width of deciduous teeth were recorded in previous studies.[21–23] But the present study considered the diagonal measurements also as a predictor variable in determining sex and it was applicable in deriving the discriminant functions. To the best of our knowledge, this is a maiden attempt. The present study aimed to compute a new formula using discriminant function analysis and to verify the accuracy of such methods in sex determination from deciduous dentition in children of South Indian origin.

2. Materials and methods

2.1. Sample selection

The sample consisted of 280 children who were selected from 1200 subjects aged between 5 and 13 years of South Indian origin by simple random sampling method. Among the selected 280, only 183 (93 girls and 90 boys) met the inclusion and exclusion criteria. The sample for the study included teeth that were fully erupted which had no caries, restorations or any history of orthodontic treatment. Ethical committee approval was obtained from the Institutional Ethical Committee, Namakkal district, Tamilnadu state, India.

2.2. Procedures and parameters

Alginate impressions (Tropicalgin, Zhermack Clinical, New Jersey, U.S.A.) of the upper dental arch were made using perforated trays and casts were poured immediately with type IV dental stone. A digital vernier calliper calibrated to an accuracy of .01 mm (Mitutoyo Absolute Digimatic Sliding Caliper, Tokyo, Japan, .05 mm resolution) was used for obtaining the measurements. Teeth considered for measurement were both the upper canines, first molars and second molars (tooth nos. 53, 63, 54, 64, 55 and 65) (Figs. 1 and 2).

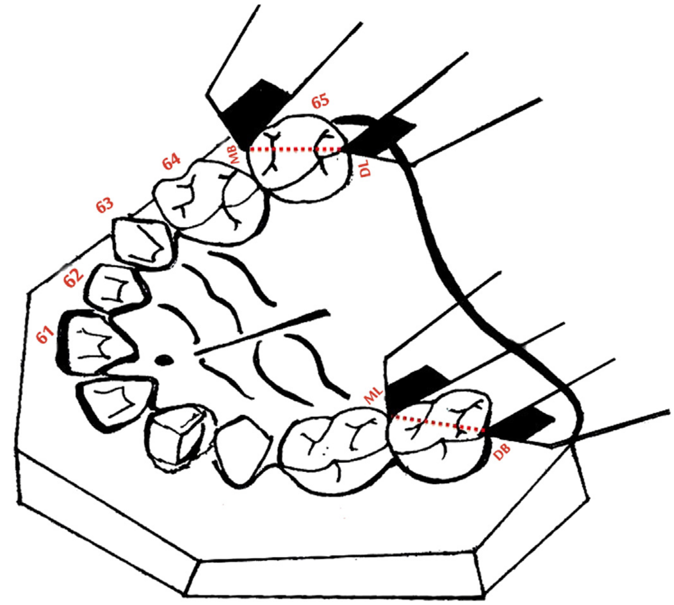

Fig. 1. Deciduous maxillary cast showing the measurement methods for mesiodistal (MD) and buccolingual (BL) dimensions with tooth numbering of right quadrant.

Twenty different tooth measurements were recorded. The canines were measured in two dimensions, the MD diameter and the BL diameter, and the molars in four different dimensions which included the MD diameter, the BL diameter along with the diagonal measurements such as mesiobuccal–distolingual (MB–DL) diameter and distobuccal–mesiolingual (DB–ML) diameter. All measurements were recorded by one of the investigators and calibration was done by the senior author.

For a rotated or malposed tooth, the measurement was made between points on the proximal surfaces of the crown where it was

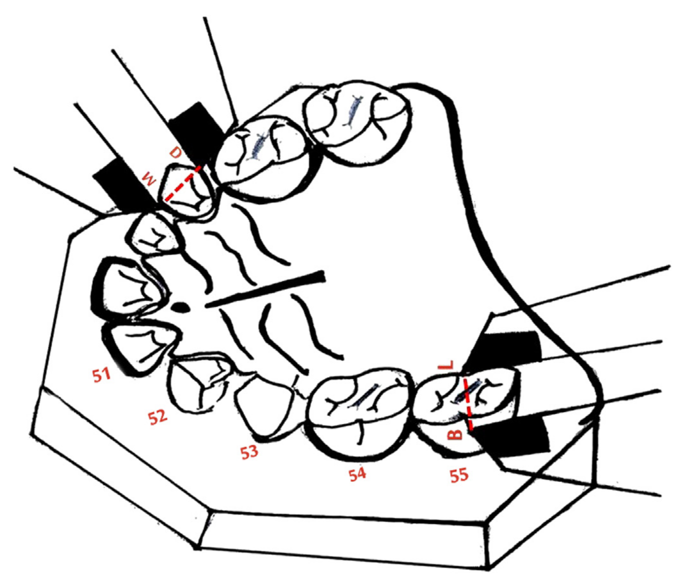

Fig. 2. Deciduous maxillary cast showing the measurement methods for mesiobuccal–distolingual (MBDL) and distobuccal-mesiolingual (DBML) dimensions with tooth numbering of left quadrant.

perceived that contact with the adjacent teeth would normally occur.[7]

Sex differences were also compared between teeth by the percentage of sexual dimorphism according to Garn et al.[24] An average measure of MD diameters and percentage dimorphism has been computed using the ratio expression $100 \times [(M - F)/F]$, where M is the mean male tooth dimensions and F the mean female tooth dimension. Dimorphic ranking was then attributed, allotting the first rank to the tooth presenting the highest dimorphism and the last rank to the one presenting the lowest ratio.

2.3. Reliability measures

To estimate intra-observer variability, a second determination was made after 2 months by the same investigator. Intraclass correlation coefficient (ICC) was used to access the intra-observer variability. The ICC for all the measurements was .965 (95% confidence interval: .948–.972), indicating that the difference attributed to measurement error was very small or practically non-existent.

2.4. Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Science (SPSS) version 17.0 software. Descriptive statistics (mean and standard deviation) was computed for each variable and Student's *t*-test was used to determine if statistically significant differences existed between the sexes. The level of significance was kept at $p \leq 0.05$.

All the predictor variables were subjected to stepwise discriminant function analysis, which has the potential to optimally separate the sexes; further the statistical significance was assessed using Wilks' lambda. The variables having the higher discriminant function coefficient were included in the discriminant function for developing the formula

$$D_i = K + d_{i1}z_1 + d_{i2}z_2 + \ldots + d_{ip}z_p$$

where D_i is the discriminant function score, d_i is the discriminant function coefficient, z is the score of the predictor variable and K the discriminant function constant.

3. Results

The intra-observer reliability calculated during the second examination after 2 months revealed the ICC value to be .965. Hence the measurements made at two different points showed negligible difference. Therefore the initial measurements were taken into consideration for calculation.

In the observed mean dimensions, male values were higher than the female values except for teeth 63 and 64. By using Student's *t*-test, the different predictor variables of teeth selected (tooth nos. 53, 63, 54, 64 and 55) between male and females were found to be significant ($p < 0.05$). Remarkable sexual dimorphism was found in the mean MD dimension of 53, 54 and 64, BL dimension of 54, DB–ML of 54, 64 and 55 and MB–DL of 55 (Table 1).

Table 1
Student '*t*' test for the comparison of all the predictor variables of all teeth selected (53, 63, 54, 64, 55, 65) between both the sexes.

Tooth no.	Independent variable	Male	Female	Difference	*T* test	Sig
		μ ± SD	μ ± SD			
53	MD	6.57 ± .596	6.48 ± .274	.0876	1.292	.000
	BL	5.94 ± .582	5.88 ± .379	.0593	.827	.085
63	MD	6.28 ± .331	6.44 ± .448	−.1636	−2.825	.011
	BL	5.77 ± .312	5.78 ± .393	−.0063	−.122	.238
54	MD	6.68 ± .656	6.40 ± .463	.2862	3.441	.000
	BL	8.40 ± .640	8.18 ± .398	.2195	2.813	.001
	MBDL	8.82 ± .491	8.68 ± .560	.1355	1.752	.217
	DBML	7.46 ± .357	7.29 ± .634	.1703	2.249	.000
64	MD	6.85 ± .523	7.04 ± 1.268	−.1881	−1.316	.000
	BL	8.53 ± .565	8.49 ± .707	−.0463	.493	.025
	MBDL	8.72 ± .661	8.90 ± .577	−.1825	−2.005	.380
	DBML	7.75 ± .414	7.68 ± .829	.067	.695	.000
55	MD	8.85 ± .637	8.79 ± .708	.0611	.617	.502
	BL	9.81 ± .502	9.71 ± .579	.0991	1.246	.010
	MBDL	10.80 ± .834	10.63 ± .520	.2258	2.157	.000
	DBML	9.81 ± .846	9.25 ± .402	.56	5.784	.000
65	MD	8.90 ± .640	8.62 ± .668	.2867	2.987	.244
	BL	9.79 ± .495	9.86 ± .509	−.0689	−.935	.932
	MBDL	10.76 ± .634	10.38 ± .521	.3829	4.499	.152
	DBML	9.86 ± .651	9.48 ± .607	.3739	4.048	.270

A paired *t*-test was used to compare the corresponding teeth on each side of the arch. All the variables were significantly different at the 5% level except for MB–DL of 54–64 (Table 2).

Percentage of sexual dimorphism in MD dimensions estimated from the formula of Garns et al.[24] revealed that the right upper first molar was the most dimorphic tooth and the upper first molar of the left side was the least dimorphic of the six teeth studied (Table 3).

Table 4 shows the accuracy of the discriminant function coefficient for all the predictor variables which were included in this study, from which the highest accurate values were included for the generation of the discriminant function.

The discriminant analysis produced the best discriminant functions and the predictor variables included in the functions were BL 53, DB–ML 54, MD 64, MB–DL 64, DB–ML 64, MD 55, DB–ML 55, MD 65 and DB–ML 65, based on the greatest univariate discriminant coefficient. Before the formula was calculated with the greatest univariate discriminant coefficient, the predictor variables were subjected to a test of significance using Wilks' lambda. It was found that the entire assigned predictor variables showed statistical significance at $p < 0.05$ (Table 4).

The best discriminant function was

$$F = -11.498 + 3.522(\mathrm{MD}_{65}) + 2.896(\mathrm{DB} - \mathrm{ML}_{64}) + 2.890(\mathrm{DB} - \mathrm{ML}_{55}) - 0.647(\mathrm{DB} - \mathrm{ML}_{54}) - 0.665(\mathrm{DBML}_{65}) - 0.906(\mathrm{MB} - \mathrm{DL}_{64}) - 0.975(\mathrm{MD}_{64}) - 1.685(\mathrm{BL}_{53}) - 3.778(\mathrm{MD}_{55})^{*}$$

From the stepwise discriminant analysis, the group centroid was also generated for both the sexes. A group centroid is the mean discriminant score for each sex. A cut-off point, which separates one sex from the other, is the average of the two centroids; a smaller value than this is considered as a female and vice versa. The cut-off point between the sexes was .027. The male group centroid was 1.254 and the female group centroid was −1.227. Raw coefficients, the discriminant function coefficients, were used to calculate the discriminant score.

Table 2
Comparison of mean difference of the predictor variables between both sides.

Pairs	N	95% confidence interval of the difference		*t* Value	*p* Value
		Lower	Upper		
53–63 MD	186	.09631	.23939	4.629	.000
53–63 BL	186	.07600	.18766	4.658	.000
54–64 MD	186	−.54671	−.26866	−5.758	.000
54–64 BL	186	−.29706	−.14143	−5.559	.000
54–64 MBDL	186	−.13853	.02531	−1.363	.174
54–64 DBML	186	−.42491	−.25756	−8.046	.000
55–65 MD	186	.00757	.11286	2.257	.025
55–65 BL	186	−.11619	−.01919	−2.754	.006
55–65 MBDL	186	.10808	.23740	5.271	.000
55–65 DBML	186	−.21029	−.07719	−4.261	.000

The value obtained using discriminant function for the casts of males and females is calculated respectively. Hence it shows that this discriminant function formula can accurately identify sexual dimorphism in this population.

To assess whether it is possible to generate accurate sex models from the data collected for this study, discriminant functions were calculated and tested using cross-validation. This was performed using SPSS software and the leave-one-out method was chosen to calculate the cross-validation error rate (Table 5).

The discriminant function used in the present study describes the optimal separation between the sexes and also shows that there are significant variations between them and it is substantiated by classification accuracy of functions provided in Table 5. Hence the original grouped cases correctly classified were 92.5%.

4. Discussion

Sexual dimorphism in the size of deciduous teeth varies among populations and hence the criteria set for one population may not apply to another. Considering the fact that there are differences in odontometric features in specific populations, even within the same population in the historical and evolutional context, it is necessary to determine specific population values in order to make identification possible on the basis of dental measurements. These values can be of use in determining sex in specific cases: in individuals as well as in groups (mass disasters, archaeological sites, etc.).[25]

The coronal morphology and dimension of a deciduous tooth remain unchanged during growth and development except for specific conditions such as nutritional abnormality, inherited disorders and other pathological conditions. Hence odontometric features can be used in determining the sex after the tooth has erupted even in child skeletons or samples whose skeletal features are not defined.[26]

The study of casts has been in use in forensic dentistry for a very long time. The accessibility to measure various dimensions using geometric devices is simpler and easier using dental casts rather than direct intraoral measurements. Casts serve a greater purpose for the diagonal measurements in particular.

Table 3
Dimorphic ranks among both the sexes. Percentage of sexual dimorphism in MD dimensions.

Tooth	Male	Female	Difference	Percentage	Rank
53	6.5772	6.4896	.0876	1.349	3
54	6.6899	6.4037	.2862	4.478	1
63	6.2824	6.460	−.1636	−2.532	5
64	6.8579	7.0460	−.1881	−2.669	6
55	8.8549	8.7938	.0611	.694	4
65	8.9087	8.6220	.2867	3.332	2

Table 4
Wilk's lambda to test the significance among the predictor variables.

Wilks' lambda				
Test of function(s)	Wilks' lambda	Chi-square	Df	Sig.
1	.391	168.452	9	.000

When it is difficult to measure the MD width of the anterior teeth, diagonal measurements may be a reliable alternative.[27] In the present study, we considered the diagonal measurements also as a predictor variable in determining the sex; the variable was applicable in deriving the discriminant functions. Hence this variable will be of greater use in sex determination when malpositions such as tooth rotation, crowding and orthodontical anomalies may cause difficulty in recording width measurements. This is a maiden study in using the diagonal measurements in deciduous dentition for sex determination.

In the present study it has been identified that significant sex differences exist in odontometric features of deciduous canines and molars. It was also found that these differences were large enough to determine the sex with classification accuracy between 87.2% and 88% from cross-validation of discriminant function analysis, when using all the parameters explained in the methodology.

The male mean dimension is greater than that of the female for all the variables except for certain variables such as MD and BL of 63 and 64, MB–DL of 64 and BL of 65, which is similar to the study by Black[21] and Bravo[28] and contrary to that of Moorrees et al.[7] who found that male mean MD diameter exceeds the female mean for all the deciduous teeth.

The equation developed by this study ranges in accuracy from 87.2% to 88%. This was considerably higher when compared to that developed by Black,[21] DeVito and Saunders[22] and Zadzinska et al.[23] with 33.3–75%, 35.7–45.9% and 38.5–73.3%, respectively. This shows that the present study provides robust evidence to identify the sex in a paediatric population using its formula.

There were certain limitations associated with the sample. The sample consisted of only the canines and molars. It would also be beneficial to include the incisors to determine their contribution in sex determination, which could be a more precise reflection of the crown dimensions, in assessing the same.

The tooth that shows the greatest degree of sexual dimorphism was not the same when different studies were analysed. For example, in studies by Margretts and Brown,[13] Black[21] and Zadzinska et al.[23] it is the BL dimension of the mandibular first molar whereas in a study by Cardoso[29] it is the MD dimension of the mandibular second molar that shows the greatest degree of sexual

Table 5
Classification accuracy checked using cross validation for the developed discriminant function.

Classification results[b,c]					
		Sex	Predicted group membership		Total
			Male	Female	
Original	Count	Male	84	8	92
		Female	6	88	94
	%	Male	91.3	8.7	100.0
		Female	6.4	93.6	100.0
Cross-validated[a]	Count	Male	81	11	92
		Female	12	82	94
	%	Male	88.0	12.0	100.0
		Female	12.8	87.2	100.0

[a] Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
[b] 92.5% of original grouped cases correctly classified.
[c] 87.6% of cross validated grouped cases correctly classified.

dimorphism compared to the present study where the MD dimension of the maxillary first molar shows the greatest percentage of sexual dimorphism.

Such population variations may result from differences in the quality of environment during growth and development, particularly maternal health, which may influence tooth size. Garn et al.[30] have revealed that children with low birth weight and low birth length show notably smaller deciduous tooth crowns. Similarly, Seow and Wan[31] have shown the smallest deciduous crown dimensions in very low birth weight children compared to normal-birth-weight children who show the largest, with the low birth weight revealing intermediate dimensions. Poor environmental conditions during prenatal life, in addition to reducing overall tooth crown size, also diminish sex differences, with males being affected most remarkably.

5. Conclusion

The present study elicits the fact that the level of sexual dimorphism in deciduous crown dimensions of an Indian population is sufficiently large enough for determining sex to an accuracy of 87.2–88% from discriminant function analysis using all variables. Hence the discriminant function $(F)^*$ derived would help in sex determination in a paediatric population of South Indian origin by substituting the odontometric values in the function $(F)^*$ and referring it to the cut-off point which discriminates the sex.

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None.

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Conflict of interest
None.

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